ST. LAWRENCE
REMEDIAL ACTION PLAN
PLAN DASSAINISSEMENT
ST~LAURENT

ST. LAWRENCE RIVER REMEDIAL ACTION PLAN

TECHNICAL REPORT NO. 3

FISH TAINTING EVALUATION

July 1992

Remedial Action Plan
Plan d'Assainissement

Canada Ontario

St. Lawrence River Remedial Action Plan

Technical Report Series # 3.

St. Lawrence River Remedial Action Plan

Fish Tainting Evaluation

by

C.G. Jardine
Great Lakes Section
Water Resources Branch

July 1992

ISBN-0-7778-0087-X

FOREWORD

The Fish Tainting Evaluation study has provided background information for the development of the St. Lawrence Remedial Action Plan (RAP) currently under preparation. This study was performed at the request of the RAP Team and the Cornwall Public Advisory Committee (PAC).

ACKNOWLEDGMENTS

The author would like to thank Mike Eckersley (Ontario Ministry of Natural Resources) for his invaluable assistance in the implementation of this study, including: netting and preparing the perch fillets; caging and retrieval of the rainbow trout and preparation of the samples. Janette Anderson (St. Lawrence River RAP Coordinator, Environment Canada) provided considerable input to the study design and implementation, and to the final report. Bob Helliar (Ontario Ministry of the Environment, Southeastern Region) assisted with rainbow trout caging, water sample collection, sample preparation and sensory evaluation procedures. The assistance of Lisa Richman (Ontario Ministry of the Environment, Water Resources Branch) in the sample preparation and sensory evaluation procedures is also appreciated. Ken Flood (Ontario Ministry of the Environment, Water Resources Branch) provided the fish cages. Dan Toner (Ontario Ministry of the Environment, Laboratory Services Branch) supervised the fish tissue analyses. Andre Vaillancourt and Peter Nettleton (Ontario Ministry of the Environment, Water Resources Branch) provided the sport fish contaminant survey results and St. Lawrence dilution results, respectively. Finally, the study would not have been possible with the enthusiastic efforts of the Public Advisory Committee members and observers who volunteered as sensory panelists.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Fish tainting has historically been documented as a use impairment in the St. Lawrence River, downstream of the bleached kraft pulp and paper mill at Cornwall, Ontario. The tainting potential was shown to be significantly reduced following improvements to the mill effluent. However, a large zone in this area is still characterized by concentrations of total reactive phenolics exceeding the level that may impart taint to fish. There have been no recent sensory evaluation surveys to determine whether fish in the Cornwall - Lake St. Francis area are impaired with regard to off-flavours.

Two sensory evaluation tests were conducted in September, 1990 to address these concerns. In the first test, indigenous yellow perch were caught in Lake St. Lawrence (upstream of the mill discharge) and Lake St. Francis (downstream of the discharge). In the second test, caged rainbow trout were exposed directly downstream of the effluent diffuser for 95 hours. Trout were also caged for approximately the same period upstream of the mill to act as controls. Two separate sensory evaluations were conducted using the triangle test to determine if there was a significant difference in odour between the Lake St. Lawrence and Lake St. Francis perch, and exposed and control rainbow trout. The triangle test method involves the presentation of three samples, in which two are the same and one is different. The panelist is required to determine which sample is different. The panel consisted primarily of members of the Public Advisory Committee and other members of the public.

In the perch test, the number of correct responses was significantly different at the 95% confidence level from the chance of correctly "guessing" the odd sample. The panelists were also requested to identify if the odd sample was an "exposed" (Lake St. Francis) or ""control" (Lake St. Lawrence) perch. The number of correctly identified samples was also significantly different at the 95% confidence level from the chance of correctly "guessing" if the sample was an exposed or control fish. It is concluded that sensory evaluation panel could distinguish a significant difference in the odour of perch from Lake St. Lawrence and Lake St. Francis under the test conditions of this study. In addition, the panel could distinguish a noticeable taint in the Lake St. Francis perch in those tests where they may have correctly differentiated between the samples from each lake. The panelists' comments generally indicate that many found a definite difference in odour between the perch from the two locations, and that the odour of the Lake St. Francis perch was perceived to be objectionable.

However, in the rainbow trout test the number of correct responses was not significantly different at the 95% confidence level from the chance of correctly "guessing" the odd sample. The number of correctly identified samples was also not significantly different at the 95% confidence level from the chance of correctly "guessing" if the sample was an exposed or control fish. It is concluded the sensory evaluation panel could not distinguish between caged rainbow trout exposed upstream (control) and those exposed downstream (exposed) of the Domtar effluent diffuser under the test conditions. The sensory evaluation panel also could not distinguish a noticeable taint in those tests where they may have correctly differentiated between the control and exposed samples. The panelist comments indicate that there was generally no perceived difference between the control and exposed fish. Where differences were noted, the odour was not thought to be objectionable. However, these results are not conclusive because of the high degree of effluent dilution (approximately 10,000:1) at the exposure site. Concentrations of known tainting compounds (such as phenol) are below established tainting thresholds at this site.

A comparison of the results of the twelve panelists completing both the perch and rainbow trout tests shows that the number of correct responses and percentage of correct identifications were significantly higher for the perch test.

Although the Lake St. Francis yellow perch were perceived to have a taint, no chlorophenol or chlorobenzene compounds were detected in the Lake St. Francis yellow perch used for the sensory analysis. The off-odour in the perch as opposed to the trout may, therefore, be due to the longer exposure of the indigenous species to low-levels of contaminants, or to species differences in the uptake and retention of tainting compounds. Furthermore, variability in the collection techniques used for fish from Lake St. Lawrence versus Lake St. Francis may have had an effect on the observed odour in the downstream fish. Significant differences in concentrations of some Polycylic Aromatic Hydrocarbon (PAH) compounds found in previous tissue analyses of perch from Lake St. Lawrence and Lake St. Francis leads to the speculation that the off-odour may also be due to chemical contaminants from other sources. Further studies are required on the St. Lawrence River to identify the source and magnitude of the observed off-odours in the fish.

1.0 INTRODUCTION

1.1 BACKGROUND

Since 1973, the Great Lakes Water Quality Board of the International Joint Commission (IJC) has identified Areas of Concern throughout the Great Lakes and their connecting channels where water quality objectives (either the Great Lakes Water Quality Agreement objectives, and/or provincial or state objectives) have been exceeded and uses of the areas have been impaired. The St. Lawrence River was identified as an area of concern by the IJC as a result of sediments contaminated with polychlorinated biphenyls (PCBs), concentrations of phenolic compounds and coliform bacteria above water quality objectives, and elevated organo-lead concentrations in fish. The area of concern includes the Maitland, Ontario area and the reach from Cornwall - Massena (Ontario and New York) downstream through Lake St. Francis (including the Quebec portion). There are currently two Remedial Action Plan (RAP) programs underway for the St. Lawrence River area of concern. This study was undertaken as part of the RAP process for the Cornwall - Lake St. Francis area in Ontario and Quebec. This area is one of the seventeen Canadian Areas of Concern in the Great Lakes for which a RAP is being developed.

Tainting of fish caught in the St. Lawrence River downstream of the Domtar pulp and paper mill in Cornwall has been of concern for many years. In 1964, the Ontario Water Resources Commission, in conjunction with the Ontario Department of Lands and Forests, carried out a series of sensory panel tests to investigate the presence/absence of off-flavours in several species of fish collected from the St. Lawrence River upstream and downstream of Cornwall. The results of the tests indicated that the river water in the vicinity of Cornwall imparted an off-flavour or odour to the flesh of a large percentage of fish of several species. Although the frequency and intensity of the taint declined downstream, considerable flavour impairment occurred for a distance of at least 20 km. When the odours of several effluents were presented for comparison, wastes from the Domtar Pulp and Paper Company at Cornwall were deemed to most closely resemble the foreign flavour in the fish. The inference was that discharges from the Domtar plant were the source of the tainting compounds.

Farmer *et al.* (1973) and Cook *et al.* (1973) found a significant taint in perch exposed to untreated whole mill effluent and to several individual kraft mill condensates from the Domtar mill. Hedonic scale testing of fish exposed to biologically treated effluent sources showed that these fish were judged to be less objectionable than fish exposed to various combinations of the problem effluent

sources. However, triangle tests showed that the flavour of indigenous perch caught upstream and downstream of the mill was not significantly different.

The subsequent installation of an effluent diffuser in 1971, and the shutdown of the sulphite mill and construction of a clarifier in 1972, helped to reduce the zone affected by tainting substances. In 1979, an on-site study showed the tainting threshold to range from 0.2 - 1.0% (v/v) (Megraw 1979). Using chemical analysis of various Domtar effluents and taste threshold data from the literature, Findlay and Naish (1979) determined that phenols (specifically guaiacol and syringol), low boiling hydrocarbons, resin acids and total reduced sulphur compounds (TRS) were potential tainting agents. In 1983, Domtar carried out a dispersion and dilution study to evaluate the effectiveness of modifications made to the diffuser port to improve mixing, and to re-evaluate the tainting propensity of the mill effluent in order to define a zone of impact (Findlay *et al.* 1983). Results of this study indicated the tainting potential of the effluent ranged from 0.25 - 0.40% (v/v). The zone of impact was relatively small, with less than 2% of the river volume being affected 470 meters downstream of the diffuser.

There have been no recent angler complaints of fish tainting to the Cornwall district offices of the Ontario Ministry of the Environment or the Ministry of Natural Resources. However, the Cornwall section of the St. Lawrence River is still characterized by a large zone of elevated concentrations of total reactive phenolics (as analyzed by the 4-aminoantipyrene test). According to the Ontario Provincial Water Quality Objective for total phenols, concentrations above 1 μg/L may result in the tainting of edible fish flesh (Ontario Ministry of the Environment 1984).

To address concerns about the potential for imparting taint to the fish in this area, and to provide final confirmation of the present existence or nonexistence of this use impairment, a controlled fish tainting evaluation was conducted by the RAP team in September, 1990. This evaluation involved the sensory evaluation of both indigenous perch netted in Lake St. Lawrence (upstream of Domtar) and in Lake St. Francis (downstream of Domtar), and of rainbow trout exposed *in situ* upstream and downstream of the mill effluent discharge. The sensory panel evaluation involved members of the St. Lawrence River Public Advisory Committee (PAC), RAP team members and public observers.

1.2 STUDY OBJECTIVES

The main objectives of the study were to determine if there was a significantly different odour in the flesh of: (1) indigenous perch caught in Lake St. Lawrence and Lake St. Francis; and (2) caged rainbow trout exposed upstream and downstream of the Domtar pulp and paper mill diffuser outfall.

A secondary objective was to determine which compounds may be contributing to tainting by analyzing selected fish tissues.

2.0 METHODS

2.1 FIELD METHODS

2.1.1 Perch Collection

Yellow perch (*Perca flavescens*) were netted in Lake St. Lawrence (upstream of the mill and the Saunders power dam) on September 13, 1990 and angled in Lake St. Francis (downstream of the mill) on September 15, 1990. The sampling locations are shown in Figure 1. The fish were filleted and skinned. The skinless fillets were vacuum sealed in polyethylene bags using a Decosonic™ (No. 828) Vacuum Bag Sealer, and frozen until the day of the sensory evaluation.

2.1.2 Rainbow Trout Exposure

Rainbow trout (*Salmo gairdneri*) were chosen as a test species because they are readily obtained, and have a relatively high fat content. The organic compounds that cause taint tend to be selectively retained in the lipophilic tissues.

Disease free rainbow trout, 20 to 25 cm in length , were purchased from a local fish farm and shipped by car in coolers to Cornwall. The fish were acclimated to a water temperature of approximately 12°C for 40 minutes prior to caging. No mortality or signs of stress were noted in the fish prior to caging.

The St. Lawrence fish exposures were conducted from September 14 to 18, 1990. The fish exposure locations are shown in Figure 1. Unfortunately, the extremely fast current in the main channel of the river physically prohibited the anchoring of cages in close proximity to the diffuser

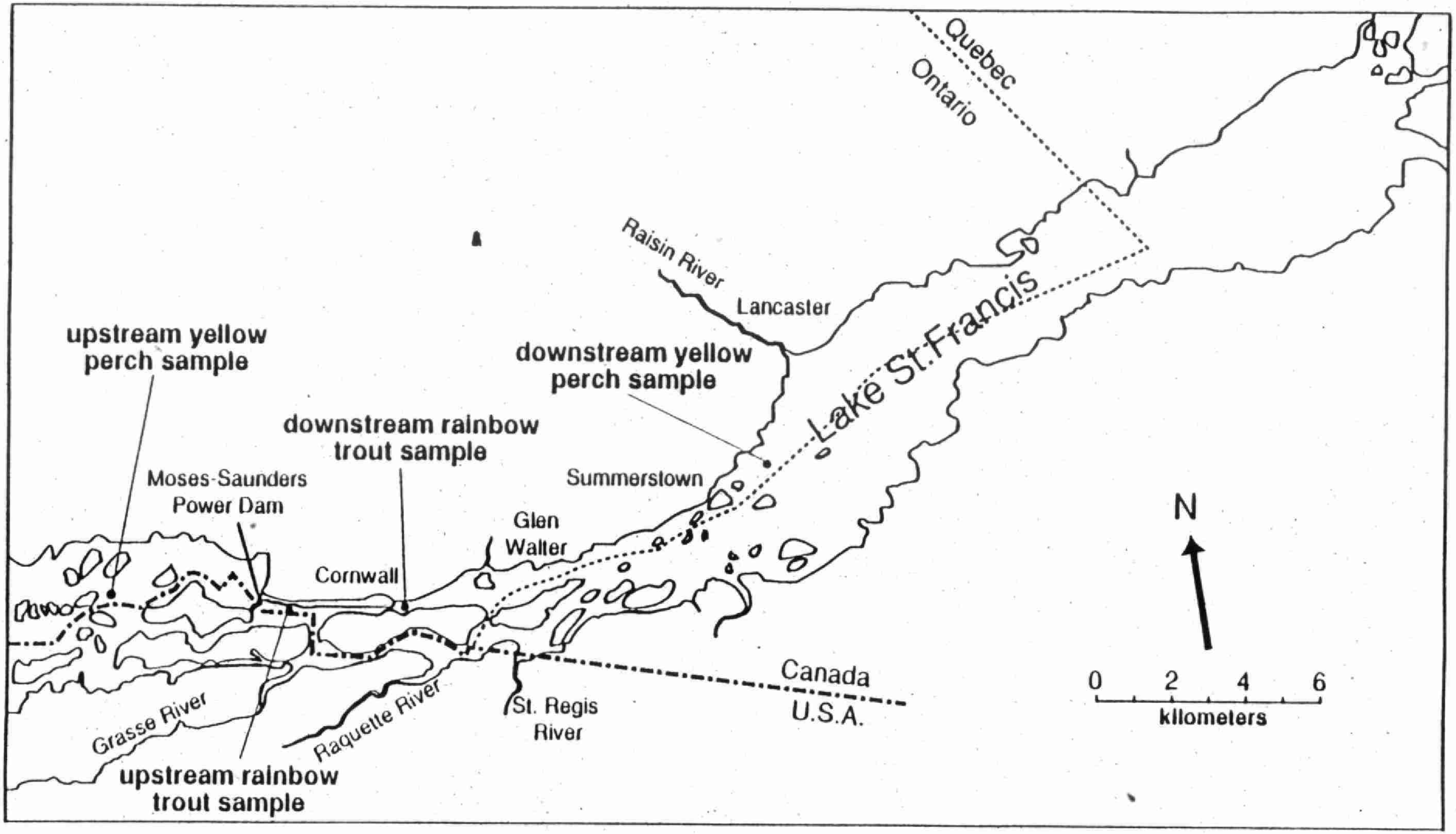

Figure 1. Sampling locations for yellow perch and caged rainbow trout

outfall. In addition, the high flows were thought to represent an unacceptable level of stress for caged fish. The downstream exposure site was thus located in a small sheltered embayment approximately 1000 meters downstream of the discharge. The cages used for the exposure were constructed from 1.9 cm polyvinylchloride (PVC) pipe frame in a triangular configuration of 0.5 meters in length and depth. The frame supported a 0.6 cm mesh nylon bag with a draw string closure at the top. The cages were free-floating, with the cage top at the water surface, and were held in place by a rope and anchor. One cage containing 20 fish was placed at both the control site and the exposure site. An empty plastic container was tied to the cages as a navigational and retrieval marker. The fish were not fed during the exposure period.

There is no consensus in the literature on the exposure period necessary to attain the maximum degree of flavour impairment. Shumway and Palensky (1973) recommended 48 hours as a standard exposure period on the basis that attainment a slightly higher degree of off-flavour would require more than a one-week exposure (the maximum used in their tests). Gordon *et al.* (1980) found that, for concentrations of pulp mill effluent between 1% to 5% (v/v), tainting did not increase when fish were exposed for periods in excess of 5 hours up to 96 hours. GESAMP (1989) and Poels *et al.* (1988) recommended a 24 hour exposure period as an acceptable duration. Due to the high degree of dilution and fast flow at the exposure site, an extended exposure period of approximately 96 hours was selected for this study to ensure that the maximum uptake of tainting compounds would be realized.

The fish were collected on the day of the sensory evaluation (September 18, 1990). The control fish were exposed for 94.5 hours and the exposed fish for 95 hours. Two trout in the downstream cage were dead and showed signs of being scavenged, possibly by an eel or pike. The fish were transported live in coolers filled with water from the caging site, and were sacrificed and filleted within two hours of collection.

Water samples were collected for analyses on September 14 and 19, 1990 and submitted for analyses of selected pulp mill indicator parameters.

2.2 TAINTING EVALUATION

2.2.1 <u>Sample Preparation</u>

Sample preparation was the same for the perch and rainbow trout tests. The flesh of all fish from each individual exposure and/or geographic location were minced together in a Sears blender with a

glass container. Skinless perch fillets were used. However, the skin was kept on the rainbow trout fillets to more closely emulate actual consumption conditions, as rainbow trout is frequently cooked without removing the skin. In addition, many of the organic compounds associated with tainting are associated with the lipophilic layer just below the skin in this species. Combining all fillets eliminated any odour variability between individual fish. The fish fillets were kept partially frozen to allow better mixing, and to minimize the loss of any volatile compounds.

Five gram aliquots (±0.1 gm) were weighed on a Mettler PE 3600 top-loading balance, and immediately wrapped in aluminum foil packets of 80 mm by 40 mm folded dimensions. Approximately equal proportions of muscle and skin were included in each trout sample. A three-digit code was marked on each packet with a wax pencil for identification during sensory analysis. The packets were then vacuum sealed. Three packets were sealed in each bag, corresponding to each triangle test set. The set number was marked in wax pencil on the outside of the bag.

Care was taken that the tissue was exposed to the air as little as possible during the blending and weighing of the individual samples to minimize the loss of any volatile compounds. Only glass and stainless steel instruments were used in the preparation of the samples.. Soap was not used by the investigators preparing the samples either prior to or during the preparation procedure.

2.2.2 Sensory Evaluation

The assessment of taint was conducted using a sensory evaluation method called the triangle test. This method has been advocated as a standardized test for identifying possible tainting in fish (Poels *et al.* 1988 and GESAMP 1989). In the triangle test, three samples are presented to the panelist. Two of the samples are the same, and one is different. The panelist judges which sample he or she believes is different. This is a forced choice method; the panelist cannot abstain from a decision even if he or she does not detect any difference between the samples. The triangle test has the advantage of having a smaller statistical probability of a panelist "guessing" whether a sample is tainted or untainted (i.e. 33%, as opposed to 50% for a test involving the comparison of two samples). Forced choice, three sample tests are the most sensitive sensory testing methods, and hence are most applicable where the expected difference between samples is slight (American Society for Testing and Materials 1968).

A modified version of the triangle test was used in this study, in which the panelist was further required to state whether the odd sample was tainted or untainted, and provide any comments and/or descriptors for each sample set. This modification was first used by Cohen *et al.* (1960).

Six sets of three samples were used to produce a balanced design of every possible presentation order combination of control and exposed fish. Each set consisted of either one sample of exposed fish and two of control fish, or one sample of control fish and two of exposed fish. Each combination of exposed and control samples was different. The order of presentation of each combination was assigned randomly, and was different for the perch test and the rainbow trout test.

The panel sessions were held in the kitchen facilities of the Robert H. Saunders St. Lawrence River Generating Station on September 18 and 19, 1990. Four to six evaluations were made at one time. All perch tests were completed on the evening of September 18; however, the late hour required that eight of the sixteen evaluations for the rainbow trout test be completed on the subsequent night. The panelists consisted of seventeen members of the PAC or public observers. Two members of the study team participated in the trout test only. All panelists were non-smokers, and regular fish consumers. The PAC had been informed of the background, objectives and procedures for the tainting study, and were requested to participate in the sensory evaluation, through an information sheet provided prior to the session. The PAC was also briefed as a group on the study plan and sensory evaluation procedures prior to commencement of the evaluations on September 18, 1990. The criteria for participation were: a) panelists must like fish; b) panelists should be non-smokers; c) panelists should refrain from eating or drinking (other than water) for 30 minutes prior to each session; and d) panelists should avoid the use of perfume, aftershave or scented soaps on the day of the sensory evaluation.

The sealed samples were placed in 1 L beakers containing approximately 600 mL of hot water. The water in these beakers was heated to boiling on the stove, and maintained at this temperature for at least 20 minutes. This resulted in a sample temperature of 60°C. To facilitate nonstop testing, additional samples were heated in a pot of boiling water, and placed in beakers of boiling water just prior to evaluation. For presentation to the panelists, the beakers were placed on warming elements in the sensory evaluation area. The samples remained sealed in the polyethylene bag from the time of preparation until opened by the panelist for evaluation. This ensured that there was no loss of volatile compounds prior to the sensory evaluation. Panelists were requested to remove only one packet from the hot water at a time, and to complete their evaluation of this set of samples before proceeding to the next set, to ensure that the samples were maintained at optimum temperature. Completed samples were removed after each evaluation to prevent cross-over of odours between samples.

Panelists were given a dilute lemon solution (approximately 30 mL of lemon juice to 1 L of room temperature water) as a rinsing agent, and unsalted soda crackers were provided to clear the palate between samples. Panelists were requested to evaluate which sample was different from the other two. A decision was required even if they could not detect a difference. Panelists were further requested to indicate whether the odd sample was "tainted" or "untainted", and to provide any comments on the evaluation or odour of the samples. If no difference was detected, this was to be indicated in the comments section. Because of the unknown nature of any compounds in the fish tissue, an odour evaluation only was required. The questionnaire and instructions provided to the panelists for the perch test are given in Figure 2. The questionnaire for the trout test differed only in the three digit codes used to identify the samples.

3.0 RESULTS AND DISCUSSION

3.1 PHYSICAL AND CHEMICAL WATER QUALITY

The flow of the St. Lawrence River on September 18, 1991 was 7396 m^3 per second. The dilution ratio at the downstream caging site was estimated to be 10,000:1 (P. Nettleton pers. comm.).

Chemical water quality data collected during the fish exposure period are summarized in Table 1. Sodium, chloride, sulphates and conductivity were essentially the same at the upstream and downstream sites. Total Kjeldahl Nitrogen (TKN) decreased slightly from upstream to downstream. Total phosphorous increased from the upstream to downstream sites, particularly on September 14, 1990. Total reactive phenol also increased from upstream to downstream, although the magnitude of the increase at the actual downstream caging site was relatively small. Shumway and Palensky (1973) found that the highest concentration of phenol that did not impair the flavour of rainbow trout was 5.6 ppm (or mg/L), whereas the maximum concentration of phenol at the exposure site was approximately 0.8 ppb (or ug/L).

Effluent quality data for September 14 - 18, 1990 is summarized in Table 2. Table 3 summarizes additional effluent data collected on September 12, 1990. In addition to conventional parameters, phenol, tetrachlorobenzene, some polycyclic aromatic hydrocarbons (PAHs) and resin acids were detected in the effluent.

ST. LAWRENCE RIVER REMEDIAL ACTION PLAN
FISH TAINTING ODOUR EVALUATION

NAME ______________________________ DATE ________________

FISH SPECIES ____Perch________________________________

Six sets of three coded samples are provided. Each set should be evaluated separately, in the order listed. In each set, two of the three samples are identical, and the third is different.

To evaluate the samples, tear off the end of the foil packet and open it as much as possible. Sniff the contents three times, then fold the end of the packet to reclose the packet. Wait approximately 15 seconds, and repeat the procedure for the other two samples in the set. Test the samples separately and in the order indicated. Check the odd sample and indicate whether the odd sample is tainted or untainted. Record any additional comments you may have describing the odour of the sample(s) you believe is (are) tainted.

Rinse between each sample with the water provided and take a bite of cracker after smelling each sample.

	Code	Check odd sample	Odd sample is: (check one)	Comments
SET #1	417	________	Tainted ____	________
	858	________	Untainted ____	________
	139	________		________
SET #2	421	________	Tainted ____	________
	975	________	Untainted ____	________
	315	________		________
SET #3	740	________	Tainted ____	________
	586	________	Untainted ____	________
	678	________		________
SET #4	393	________	Tainted ____	________
	595	________	Untainted ____	________
	624	________		________
SET #5	965	________	Tainted ____	________
	792	________	Untainted ____	________
	693	________		________
SET #6	348	________	Tainted ____	________
	821	________	Untainted ____	________
	413	________		________

Figure 2. Sensory evaluation questionnaire.

Table 1. Chemical water quality during the rainbow trout exposure period.

Date	Sampling Location	Sodium (mg/L)	Chloride (mg/L)	Sulphates (mg/L)
September 14, 1990	Upstream cage site	8.4	17.8	18
	Downstream cage site	8.0	16.1	17
September 18, 1990	Upstream cage site	11.6	23.8	24
	Downstream cage site	11.9	23.9	25

Date	Sampling Location	Total Kjeldahl Nitrogen (mg/L)	Total Phosphorous. (mg/L)	Conductivity (umhos/cm)
September 14, 1990	Upstream cage site	0.27	0.012	232
	Downstream cage site	<0.02	0.220	228
September 18, 1990	Upstream cage site	0.11	0.008	304
	Downstream cage site	<0.02	0.070	306

Date	Sampling Location	Phenolics (Unf. reactive) (ug/L as phenol)
September 14, 1990	Upstream cage site*	NA
	Downstream cage site	0.6
September 18, 1990	Upstream cage site	<0.2
	Downstream near channel	5.0
	Downstream mid-channel	0.6
	Downstream cage site **	0.8

* Sample broken in transit - value is Not Available.
** Sample broken in transit - value calculated using an effluent phenol concentration of 77.9 ug/L and dilution ratio of 10,000:1.

Table 2. Domtar effluent quality on September 14 to September 28, 1990.

Date	Flow (Av. daily) (m3/sec)	Chemical Oxygen Demand (mg/L)	pH	Conductivity (25oC) (unhos/cm)	Total Suspended Solids (mg/L)
September 14, 1990	127000	490	6.9	1093	317
September 15, 1990	136000	485	7.2	1162	60
September 16, 1990	141000	569	7.4	1160	65
September 17, 1990	139000	470	6.6	1166	76
September 18, 1990	133000	431	7.1	1013	69

Date	Biochemical Oxygen Demand (5-day) (mg/L)	Adsorbable Organic Halides (mg/L)	Dehydro-abietic acid (mg/L)	Di-chloro-dehydro-abietic acid (mg/L)
September 17, 1990	162	4.9	0.361	0.009
September 18, 1990	150	2.8	0.275	<0.005

Note: A "<" preceding a number indicates that this value was at or below the detection limit.

Table 3. Domtar effluent quality for parameters measured monthly (September 12, 1990). Data is for detected parameters only.

Parameter	Units	Concentration
Total Kjeldahl Nitrogen	mg/L	3.8
Nitrates (total)	mg/L	0.15
Phosphorous (total)	mg/L	0.3
Sulphide	mg/L	0.22
Chloroform	ug/L	269
Benzene	ug/L	5.8
Toluene	ug/L	8.5
Acenaphthylene	ug/L	5.8
Fluoranthene	ug/L	6.1
Naphthalene	ug/L	8.5
Phenanthrene	ug/L	19.4
Pyrene	ug/L	2.8
m-cresol	ug/L	5.0
o-cresol	ug/L	5.1
p-cresol	ug/L	5.0
Phenol	ug/L	77.9
1,2,3,5-tetrachlorobenzene	ug/L	0.01
Isopimaric acid	ug/L	0.04
Levopimaric acid	ug/L	0.01
Neoabietic acid	ug/L	0.16
Oleic acid	ug/L	0.14
Pimaric acid	ug/L	0.01

3.2 SENSORY RESULTS

3.2.1 Perch Test

For the purpose of this discussion, a "correct response" or "correct judgement" means the panelist correctly determined which sample of the three presented was different from the other two. A "correct identification" means the panelist correctly identified the different sample as a control or exposed fish. Correct identifications are only applicable to those samples that were correctly judged as different (Larmond 1977).

Analysis of the results of a triangle test is based on the probability that if there is no detectable difference, the odd sample will be selected by chance one-third of the time. Analysis of the correct identifications for each correct response is based on a 50% probability of a panelist selecting a sample by chance (American Society for Testing and Materials 1968 and Larmond 1977). The number of correct responses was compared with published tables giving the minimum number of correct selections required for a significant response in the triangle test. The number of correct identifications was compared with published tables giving the minimum number of correct selections required for a significant response in a two-sample test.

Of the 96 triangle tests conducted (six sets evaluated by each of 16 panelists), the "different" sample was correctly identified on 64 occasions , or 67% of the time. The number of correct responses was significantly different at the 95% confidence level from the chance of correctly "guessing" the odd sample. A minimum of 42 correct judgements out of 96 in a triangle test indicates a significant difference at this probability level (Larmond 1977). It is thus concluded that the sensory evaluation panel could distinguish a difference in odour between the perch from Lake St. Lawrence and Lake St. Francis.

Unfortunately, two panelists did not identify the sample as "tainted" or "untainted" in five of the correct judgements. Of the remaining 59 correct responses, 49 samples were correctly identified as either the control or exposed fish. The number of correctly identified samples was significantly different at the 95% confidence level from the chance of correctly "guessing" if the sample was a control or exposed fish . A minimum of 39 correct judgements out of 59 in a paired test indicates a significant difference at this probability level (Larmond 1977). The conclusion is that the sensory evaluation panel could distinguish a noticeable taint in those tests where they may have correctly differentiated between the control and exposed samples.

Figure 3 illustrates the number of correct responses for each panelist. In addition, the number of these samples correctly identified as the "exposed" (Lake St. Francis) or "control" (Lake St. Lawrence) perch is shown. Panelist #7 was the most sensitive member of the panel, correctly identifying both the odd sample and the identity of the sample in all six tests. Panelist #12 also responded correctly in all six test sets, and correctly identified five of the six samples. Panelists #8 and #11 correctly identified both the odd sample and the nature of the exposure in five of the six test sets.

Figure 4 illustrates the number of correct responses for each triangle test set. Again, as two panelist did not indicate whether the odd sample was a control or exposed fish, they were excluded from this analysis. The letters indicated for each test correspond to the order of presentation of the samples. For example, in set #1 the samples presented were a Control fish, then an Exposed fish and finally a Control fish. Also shown are the number of correct responses that were correctly identified as the exposed or control fish. The number of correct responses for all six presentation orders were very close, ranging from eight to ten out of a possible 14. The number of correct exposure identifications for each set were also high, and fairly consistent between sets. Presentation order does not, therefore, appear to be influencing the sensory evaluation.

The comments made by the panelists are summarized in Table 4. In general, the comments indicate that many of the panelists could strongly differentiate between the Lake St. Francis and Lake St Lawrence perch, and that the odour of the Lake St. Francis fish was perceived to be objectionable.

3.2.2 Rainbow Trout Test

The analysis of the sensory evaluation results for the rainbow trout tests was the same as the perch tests. Panelist #8 did not choose the odd sample in any of the test sets, commenting that he could not distinguish a difference between the samples. This panelist was thus eliminated from the statistical analysis. Of the 90 remaining triangle tests conducted (six sets evaluated by each of fifteen panelists), the "different" sample was correctly identified on 33 occasions, or 37% of the time. This number of correct responses was not significantly different at the 95% confidence level from the chance of correctly "guessing" the odd sample. A minimum of 39 correct judgements out of 90 in a triangle test indicates a significant difference at this probability level (Larmond 1977). It is thus concluded that the sensory evaluation panel could not distinguish between the exposed and control fish.

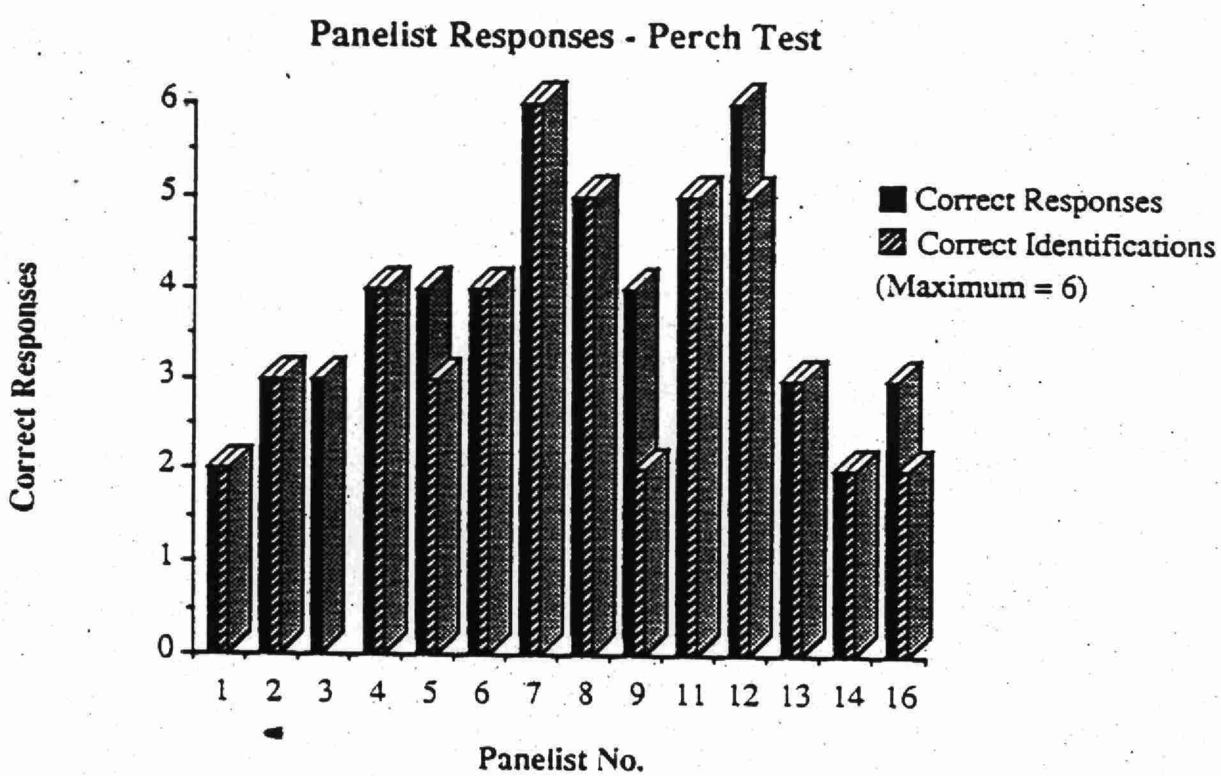

Figure 3. Correct responses and correct identifications for each panelist for the perch test.

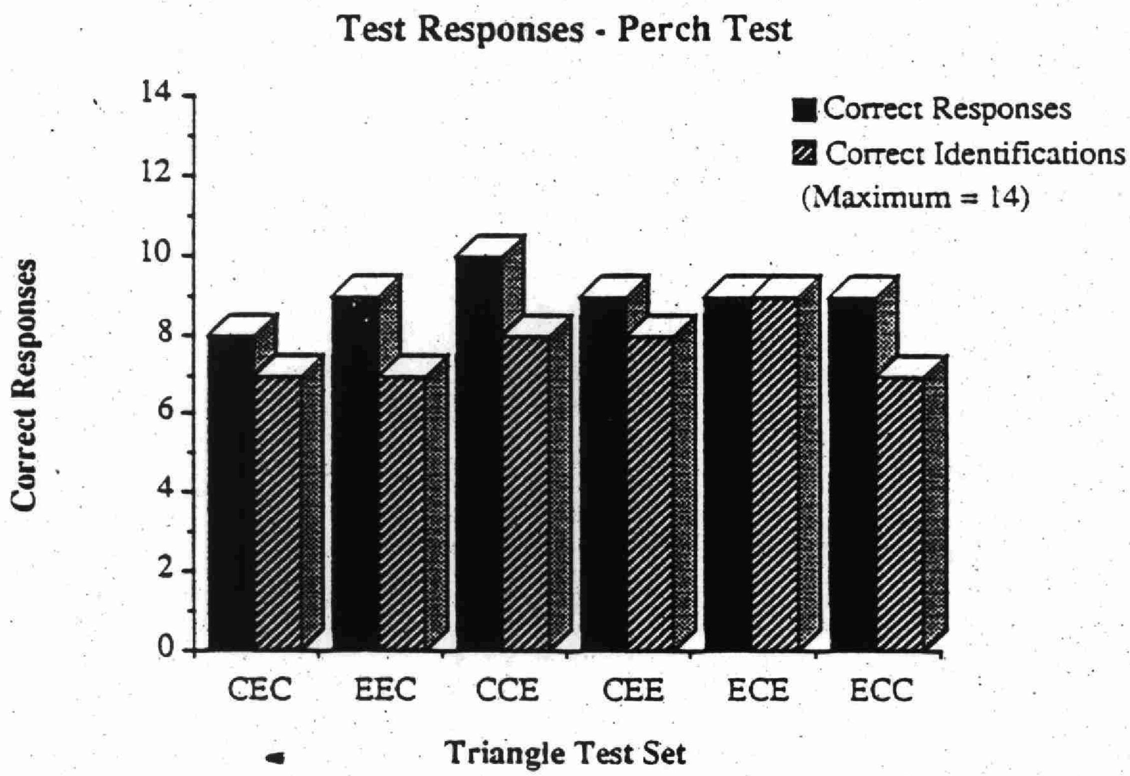

Figure 4. Correct responses and correct identifications for each triangle test set for the perch test.

Table 4. Summary of sensory evaluation results for the perch test.

Panelist	Test Set [1]	Correct Response[2]	Correct Identification[3]	Comments
1	1 (CEC)	Yes	Yes	(none)
	2 (EEC)	No	-	guess
	3 (CCE)	No	-	(none)
	4 (CEE)	No	-	other two were strong smelling
	5 (ECE)	Yes	Yes	tainted fish smelled very much like SO_2
	6 (ECC)	No	-	guess - this was a milder set
2	1 (CEC)	Yes	Yes	(none)
	2 (EEC)	Yes	Yes	(none)
	3 (CCE)	Yes	Yes	1st sample was partly tainted
	4 (CEE)	No	-	1st untainted, 2nd ptly tainted, 3rd tainted
	5 (ECE)	No	-	(none)
	6 (ECC)	No	-	(none)
3	1 (CEC)	No	-	little perceived difference
	2 (EEC)	Yes	No	odd sample somewhat stronger
	3 (CCE)	Yes	No	odd sample not as strong as previous set
	4 (CEE)	No	-	strongest yet
	5 (ECE)	No	-	"
	6 (ECC)	Yes	No	difficult on this sample
4	1 (CEC)	No	-	strong taint in other two samples
	2 (EEC)	Yes	Yes	"
	3 (CCE)	Yes	Yes	(none)
	4 (CEE)	No	-	odd sample strong smell, but < other 2
	5 (ECE)	Yes	Yes	(none)
	6 (ECC)	Yes	Yes	strong taint
5	1 (CEC)	Yes	No	not guessing
	2 (EEC)	Yes	Yes	tainted samples really stunk
	3 (CCE)	Yes	Yes	I would not eat the tainted one
	4 (CEE)	No	-	guessing - all smelled fairly similar
	5 (ECE)	Yes	Yes	possible that 2 samples may be "tainted"
	6 (ECC)	No	-	didn't smell as bad as some of the others

continued . . .

Table 4. Summary of sensory evaluation results for the perch test (continued).

Panelist	Test Set [1]	Correct Response[2]	Correct Identification[3]	Comments
6	1 (CEC)	No	-	odd sample smelled bad
	2 (EEC)	Yes	Yes	odd sample smelled OK
	3 (CCE)	No	-	odd sample smelled bad
	4 (CEE)	Yes	Yes	odd sample smelled OK
	5 (ECE)	Yes	Yes	"
	6 (ECC)	Yes	Yes	odd sample smelled bad
7	1 (CEC)	Yes	Yes	it stinks - I would not eat it
	2 (EEC)	Yes	Yes	(none)
	3 (CCE)	Yes	Yes	(none)
	4 (CEE)	Yes	Yes	(none)
	5 (ECE)	Yes	Yes	(none)
	6 (ECC)	Yes	Yes	(none)
8	1 (CEC)	Yes	Yes	(none)
	2 (EEC)	No	-	(none)
	3 (CCE)	Yes	Yes	(none)
	4 (CEE)	Yes	Yes	(none)
	5 (ECE)	Yes	Yes	(none)
	6 (ECC)	Yes	Yes	(none)
9	1 (CEC)	Yes	Yes	(none)
	2 (EEC)	No	-	(none)
	3 (CCE)	Yes	No	(none)
	4 (CEE)	Yes	No	(none)
	5 (ECE)	No	-	not sure
	6 (ECC)	Yes	Yes	(none)
10	1 (CEC)	Yes	?	(none)
	2 (EEC)	Yes	?	petroleum smell at first
	3 (CCE)	Yes	Yes	stagnant water smell
	4 (CEE)	Yes	No	"
	5 (ECE)	Yes	?	(none)
	6 (ECC)	Yes	Yes	stagnant water/earthy smell

continued . . .

Table 4. Summary of sensory evaluation results for the perch test (continued).

Panelist	Test Set [1]	Correct Response[2]	Correct Identification[3]	Comments
11	1 (CEC)	No	-	smells duller than others
	2 (EEC)	Yes	Yes	smell isn't as strong as others
	3 (CCE)	Yes	Yes	a bit stronger smell than others
	4 (CEE)	Yes	Yes	slightly less strong smell
	5 (ECE)	Yes	Yes	not as strong smelling
	6 (ECC)	Yes	Yes	much stronger smell
12	1 (CEC)	Yes	Yes	strong smell
	2 (EEC)	Yes	No	"
	3 (CCE)	Yes	Yes	"
	4 (CEE)	Yes	Yes	"
	5 (ECE)	Yes	Yes	"
	6 (ECC)	Yes	Yes	"
13	1 (CEC)	Yes	Yes	poor smell -obnoxious
	2 (EEC)	Yes	Yes	pleasant smell
	3 (CCE)	No	-	a bit on the unpleasant side - others rotten
	4 (CEE)	Yes	Yes	unpleasant - other samples sickening
	5 (ECE)	No	-	very bad - others to a lesser degree
	6 (ECC)	No	-	good
14	1 (CEC)	No	-	not totally sure
	2 (EEC)	No	-	could not detect a difference
	3 (CCE)	No	-	not as strong smell
	4 (CEE)	Yes	Yes	"
	5 (ECE)	Yes	Yes	"
	6 (ECC)	No	-	"
15	1 (CEC)	No	-	OK - not much difference
	2 (EEC)	No	-	not unpleasant, just sharper smell
	3 (CCE)	Yes	No	no unpleasant smell, just more fishy
	4 (CEE)	Yes	Yes	other two samples had sharper smell
	5 (ECE)	Yes	?	(none)
	6 (ECC)	Yes	?	very slight difference

concluded . . .

Table 4. Summary of sensory evaluation results for the perch test (concluded).

Panelist	Test Set [1]	Correct Response[2]	Correct Identification[3]	Comments
16	1 (CEC)	No	-	(none)
	2 (EEC)	No	-	(none)
	3 (CCE)	Yes	Yes	(none)
	4 (CEE)	Yes	Yes	(none)
	5 (ECE)	No	-	(none)
	6 (ECC)	Yes	No	(none)

1 Test Set Number (Presentation Order)
eg. 1 (CEC) is Set #1 (Control Exposed Control)

2 Odd sample was correctly determined

3 Odd sample was correctly identified as control or exposed fish

"-" Identification is not applicable because sample was not judged correctly

Of these 33 correct responses, 11 samples were correctly identified as either the control or exposed fish. The number of correctly identified samples was not significantly different at the 95% confidence level from the chance of correctly "guessing" if the sample was a control or exposed fish. A minimum of 23 correct judgements out of 33 in a paired test indicates a significant difference at this probability level (Larmond 1977). This indicates that the sensory evaluation panel could not distinguish a noticeable taint in those tests where they may have correctly differentiated between the control and exposed samples.

Figure 5 illustrates the number of correct responses for each panelist and the number of correct responses that were correctly identified as the exposed or control fish. Panelist #9 was the most sensitive member of the panel, correctly identifying the odd sample in four out of six tests, and correctly identifying the nature of the exposure in two out of these four responses. Panelist #5 also responded correctly in four out of the six test sets, but did not correctly identify any of these samples. Seven of the thirteen panelists correctly judging at least one sample did not correctly identify any samples.

Figure 6 illustrates the number of correct responses for each triangle test set and the number of correct responses that were correctly identified as the exposed or control fish. Although the samples sets in which an exposed fish was presented first were judged correctly slightly more frequently, the percentage of correct identifications is slightly higher in the sets in which a control fish was presented first. It is thus concluded that, as in the perch test, presentation order does not appear to influence the odour evaluation results.

The comments made by the panelists are summarized in Table 5. In general, the comments indicate that the panelists could not differentiate between the exposed and control fish, and that many of their responses were "guesses". Where a different odour was detected, it was not perceived to be objectionable. It is interesting to note that the panelists frequently confused the nature of the exposure, indicating that exposed fish were the controls and vice versa.

3.2.3 Comparison Between Tests

Twelve panelists completed both the perch and rainbow trout tests. Figure 7 compares the number of correct responses for each of these panelists for the two tests. Only panelists #5, #9, #14 and #16 scored consistently in the two tests; in all other cases the number of correct responses was higher in the perch test. Figure 8 compares the percentage of correct identifications (exposed or control) for 11 panelists between tests. Panelist #15 could not be included in this evaluation

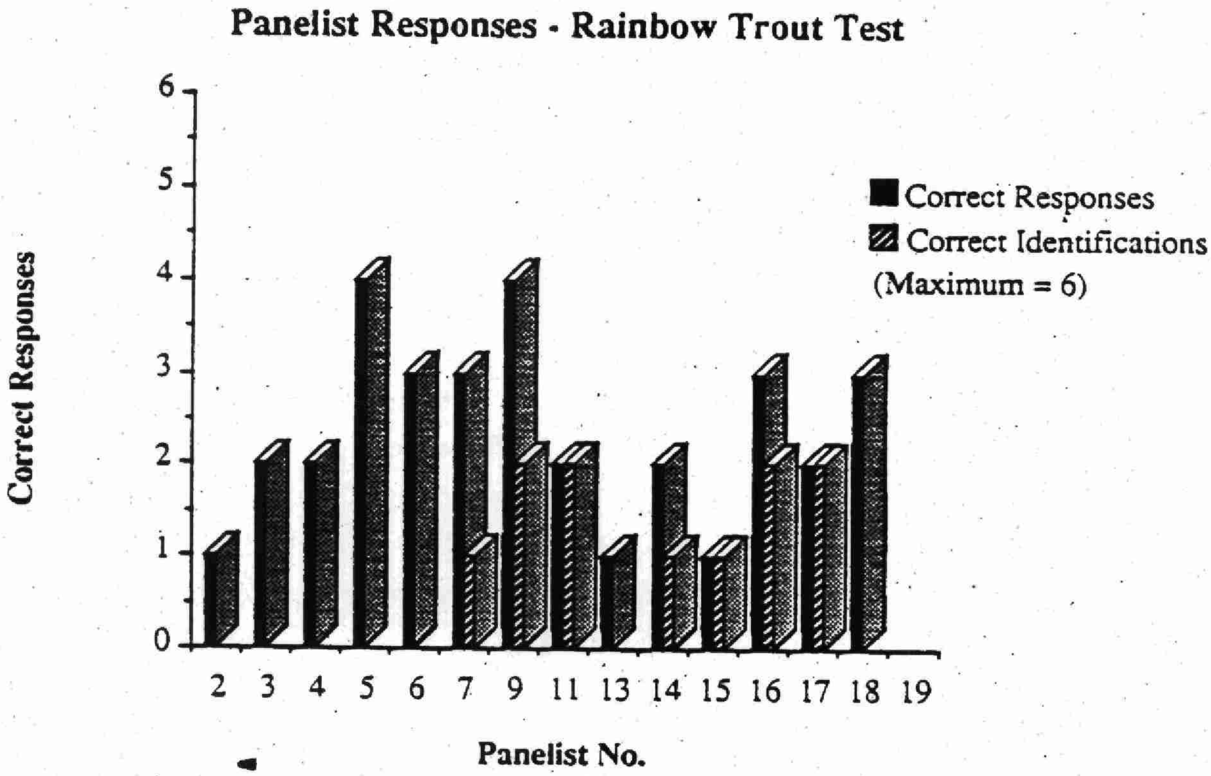

Figure 5. Correct responses and correct identifications for each panelist for the rainbow trout test.

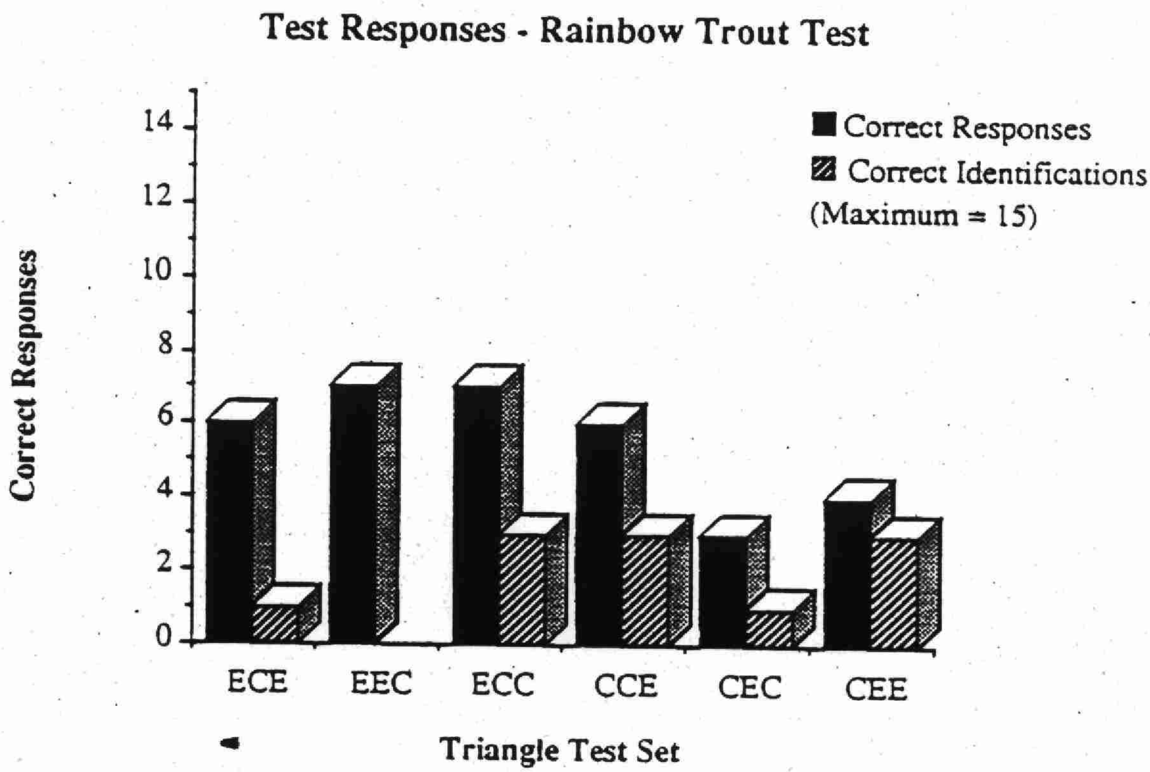

Figure 6. Correct responses and correct identifications for each triangle test set for the rainbow trout test.

Table 5. Summary of sensory evaluation results for the rainbow trout test.

Panelist	Test Set [1]	Correct Response[2]	Correct Identification[3]	Comments
2	1 (ECE)	No	-	(none)
	2 (EEC)	No	-	(none)
	3 (ECC)	Yes	No	very close
	4 (CCE)	No	-	very close
	5 (CEC)	No	-	very close
	6 (CEE)	No	-	(none)
3	1 (ECE)	No	-	definitely
	2 (EEC)	Yes	No	questionable
	3 (ECC)	Yes	No	definitely
	4 (CCE)	No	-	"
	5 (CEC)	No	-	"
	6 (CEE)	No	-	questionable
4	1 (ECE)	No	-	slight
	2 (EEC)	No	-	(none)
	3 (ECC)	Yes	No	(none)
	4 (CCE)	Yes	No	(none)
	5 (CEC)	No	-	slight
	6 (CEE)	No	-	slight
5	1 (ECE)	Yes	No	not too offensive
	2 (EEC)	Yes	No	"
	3 (ECC)	No	-	guessing
	4 (CCE)	Yes	No	"
	5 (CEC)	No	-	(none)
	6 (CEE)	Yes	No	(none)
6	1 (ECE)	Yes	No	off-flavour
	2 (EEC)	No	-	OK
	3 (ECC)	No	-	all very close
	4 (CCE)	Yes	No	OK
	5 (CEC)	Yes	No	OK
	6 (CEE)	No	-	off-flavour

continued . . .

Table 5. Summary of sensory evaluation results for the rainbow trout test (continued).

Panelist	Test Set [1]	Correct Response[2]	Correct Identification[3]	Comments
7	1 (ECE)	No	-	other samples OK, sl. stronger fishy smell
	2 (EEC)	Yes	No	odd sample more strongly fish than Set #1
	3 (ECC)	Yes	Yes	(none)
	4 (CCE)	No	-	(none)
	5 (CEC)	Yes	No	(none)
	6 (CEE)	No	-	(none)
8	1 (ECE)	No	-	hard to decide
	2 (EEC)	?	?	can't tell
	3 (ECC)	?	?	can't tell
	4 (CCE)	?	?	can't tell
	5 (CEC)	?	?	can't tell
	6 (CEE)	?	?	can't tell
9	1 (ECE)	Yes	No	guess
	2 (EEC)	Yes	No	"
	3 (ECC)	Yes	Yes	"
	4 (CCE)	No	-	"
	5 (CEC)	No	-	(none)
	6 (CEE)	Yes	Yes	(none)
11	1 (ECE)	Yes	Yes	not as strong
	2 (EEC)	No	-	quite a bit stronger
	3 (ECC)	No	-	quite a bit stronger
	4 (CCE)	Yes	Yes	a little stronger
	5 (CEC) ◄	No	-	not as strong
	6 (CEE)	No	-	foul!
13	1 (ECE)	No	-	slight difference
	2 (EEC)	Yes	No	stronger smelling than other 2
	3 (ECC)	No	-	no difference
	4 (CCE)	No	-	less strong
	5 (CEC)	No	-	slight difference
	6 (CEE)	No	-	no difference - guessing

continued . . .

Table 5. Summary of sensory evaluation results for the rainbow trout test (continued).

Panelist	Test Set [1]	Correct Response[2]	Correct Identification[3]	Comments
14	1 (ECE)	No	-	unsure
	2 (EEC)	Yes	No	(none)
	3 (ECC)	No	-	not 100% sure
	4 (CCE)	No	-	"
	5 (CEC)	Yes	Yes	unsure
	6 (CEE)	No	-	"
15	1 (ECE)	No	-	less fishy smell only, not objectionable
	2 (EEC)	No	-	guess - all smell OK
	3 (ECC)	No	-	"
	4 (CCE)	Yes	Yes	"
	5 (CEC)	No	-	very little difference - smells OK
	6 (CEE)	No	-	"
16	1 (ECE)	Yes	No	(none)
	2 (EEC)	No	-	(none)
	3 (ECC)	No	-	(none)
	4 (CCE)	Yes	Yes	(none)
	5 (CEC)	No	-	(none)
	6 (CEE)	Yes	Yes	(none)
17	1 (ECE)	No	-	(none)
	2 (EEC)	No	-	(none)
	3 (ECC)	Yes	Yes	(none)
	4 (CCE)	No	-	(none)
	5 (CEC)	No	-	(none)
	6 (CEE)	Yes	Yes	(none)
18	1 (ECE)	Yes	No	slight difference
	2 (EEC)	Yes	No	"
	3 (ECC)	Yes	No	"
	4 (CCE)	No	-	"
	5 (CEC)	No	-	"
	6 (CEE)	No	-	"

concluded . . .

Table 5. Summary of sensory evaluation results for the rainbow trout test (concluded).

Panelist	Test Set [1]	Correct Response[2]	Correct Identification[3]	Comments
19	1 (ECE)	No	-	no-noticeable difference - guessing
	2 (EEC)	No	-	"
	3 (ECC)	No	-	"
	4 (CCE)	No	-	"
	5 (CEC)	No	-	"
	6 (CEE)	No	-	"

1 Test Set Number (Presentation Order)
eg. 1 (ECE) is Set #1 (Exposed Control Exposed)

2 Odd sample was correctly determined

3 Odd sample was correctly identified as control or exposed fish

"-" Identification is not applicable because sample was not judged correctly

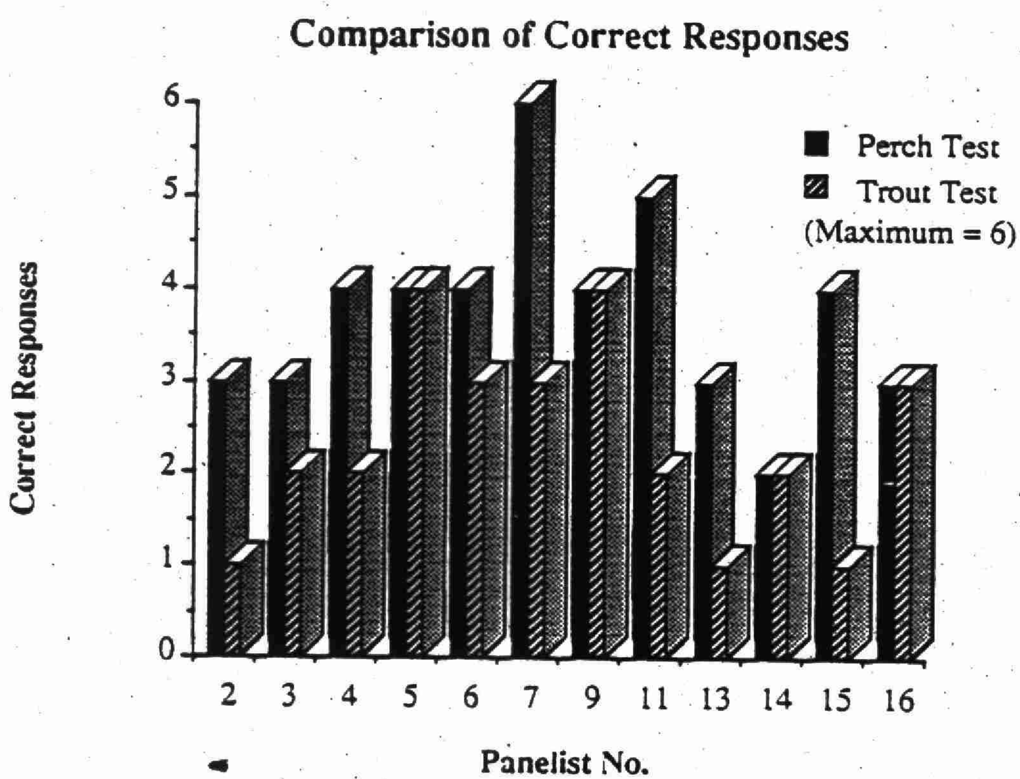

Figure 7. Comparison of the number of correct responses between the perch and rainbow trout tests.

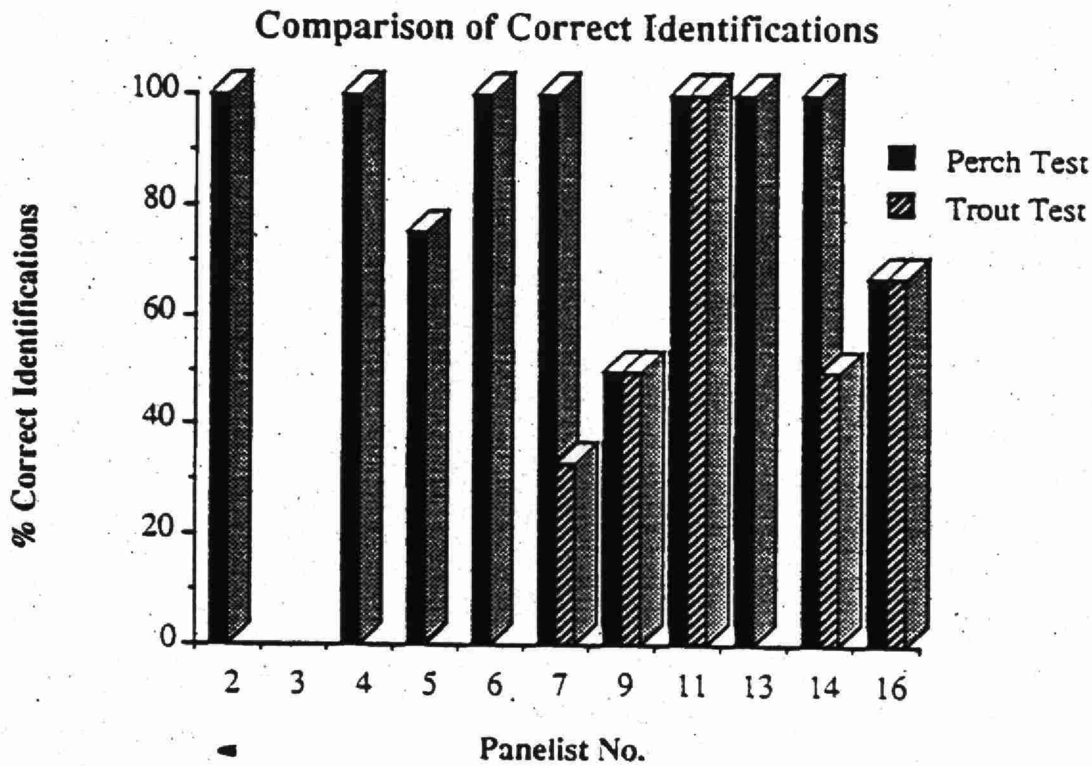

Figure 8. Comparison of thepercentage of correct identifications between the perch and rainbow trout tests.

because he did not complete this part of the questionnaire for all tests. Again, the percentage of correct identifications for the perch test were consistently greater than or equal to the trout tests. A paired t-test comparison of results for each panelist between the two tests indicates a significantly higher number of correct responses ($p = 0.0022$) and a significantly higher proportion of correct identifications ($p = 0.0029$) for the perch test than for the rainbow trout test.

3.3 FISH TISSUE ANALYSIS

As no significant taint was determined from the rainbow trout sensory evaluations, chemical analyses of the muscle tissue was not conducted for this species. Such analyses would only have been useful if the results could be correlated to organoleptic perceptions.

Samples from the yellow perch used for the sensory evaluation were analyzed for representative chlorinated organic compounds to determine if the observed difference in odour could be attributed to the effluent from the chlorobleached pulp and paper mill (Paasivirta *et al.* 1983). The muscle tissue from the Lake St. Francis fish used for the sensory evaluation was analyzed for selected chlorophenolic and chlorobenzene compounds (Table 6). Although similar samples for the Lake St. Lawrence fish were not available, these analyses had been performed on fish from the area in 1989. No chlorophenolic or chlorobenzene compounds were detected in fish from either location. The analytical detection limits for each compound are summarized in Table 6. However, these detection limits may exceed the concentrations of tainting compounds that can be detected through olfactory tests.

Tainting of finfish and shellfish by polar, cyclic and aromatic hydrocarbons has been extensively reported, particularly with respect to petroleum compounds (Connell and Miller 1981; Motohiro 1983; Tidmarsh and Ackman 1986). To determine if other compounds could be contributing to the taint, Polycyclic Aromatic Hydrocarbon (PAH) analyses, completed under the Sport Fish Contaminant program in 1988 and 1990, were examined. Of the compounds analyzed, only those compounds summarized in Table 7 were consistently detected. Concentrations of phenanthrene and fluorene were significantly higher downstream in Lake St. Francis than in Lake St. Lawrence. Concentrations of napthalene were significantly higher in Lake St. Lawrence than in Lake St. Francis. These differences lead to the speculation that some PAH compounds may be contributing to the off-odour detected in this study. A detectable concentration of phenanthrene was found in the Domtar effluent (Table 3). However, PAH compounds, including phenanthrene, are not unique to pulp and paper mill effluents. Unlike the caged trout, the Lake St. Francis perch are exposed to additional sources that may be responsible for the off-odour.

Table 6. Chlorophenol and chlorobenzene compounds analyzed for, but not detected, in the yellow perch used for the sensory analysis.

Compound	Detection Limit (ng/g wet weight)
Chlorophenols:	
2,4,6-trichlorophenol	50
2,4,5-trichlorophenol	50
2,3,4-trichlorophenol	100
2,3,5,6-tetrachlorophenol	50
2,3,4,5-tetrachlorophenol	50
Pentachlorophenol	50
Chlorobenzenes:	
1,2,3-trichlorobenzene	2
1,3,5-trichlorobenzene	2
1,2,4-trichlorobenzene	2
2,4,5-trichlorotoluene	1
2,3,6-trichlorotoluene	1
1,2,4,5-tetrachlorobenzene	1
1,2,3,4-tetrachlorobenzene	1
Pentachlorobenzene	1
Hexachloroethane	1
Hexachlorobutadiene	1

Table 7. Polycyclic Aromatic Hydrocarbons (PAHs) in yellow perch from Lake St. Lawrence and Lake St. Francis.

Parameter (ng/g wet weight)	Lake St. Lawrence*			Lake St. Francis**			t-test Comparison		
	Mean	St. Dev.	% Detected	Mean	St. Dev.	% Detected	d.f.	t-stat.	Signif. α=.05
Naphthalene	58.4	14.4	100	<22.5	5.7	40	28	-9.924	Yes
Acenaphthylene	<5.2	0.5	33	<5.0	0.0	0	20	2.024	No
Acenapthene	<10.8	2.1	90	<15.0	7.5	70	9	1.758	No
Fluorene	<22.5	7.8	71	32.4	12.1	100	12	2.365	Yes
Phenanthrene	<58.8	29.0	95	150	73.8	100	10	3.766	Yes
Fluoranthene	<20.3	11.1	71	26.1	11.4	100	17	1.342	No

* Samples were collected on October 25, 1988 under the Ontario Sport Fish Contaminant Program (n=21)

** Samples were collected on April 15, 1990 under the Ontario Sport Fish Contaminant Program (n=10)

Note: A "<" preceding a number indicates that one or more values used to calculate the mean were at or below the detection limit.

Using a similar triangle test procedure, Farmer *et al.* (1973) did not detect a significant difference in flavour between indigenous perch caught above the dam and those caught downstream at Windmill Point, Glen Walters and Summerstown. These locations are upstream of the Lake St. Francis sampling point (Figure 1). However, one experiment showed that caged perch approximately one kilometer downstream of the mill in the effluent plume were significantly tainted compared to control fish from experimental stock tanks (Cook *et al.* 1973). Clearly, the nature and source of tainting of indigenous perch in this area requires further study and clarification.

4.0 CONCLUSIONS

The sensory evaluation panel could distinguish a significant difference in the odour of perch from Lake St. Lawrence and Lake St. Francis. In addition, the panel could distinguish a noticeable taint in the Lake St. Francis perch in those tests where they may have correctly differentiated between the samples from each lake. The panelists' comments generally indicate that many found a definite difference in odour between the perch from the two locations, and that the odour of the Lake St. Francis perch was perceived to be objectionable.

However, the sensory evaluation panel could not distinguish between caged rainbow trout exposed upstream (control) and those exposed downstream (exposed) of the Domtar effluent diffuser. The sensory evaluation panel also could not distinguish a noticeable taint in those tests where they may have correctly differentiated between the control and exposed samples. The panelist comments indicate that there was generally no perceived difference between the control and exposed fish. Where differences were noted, the odour was not thought to be objectionable. The panelists frequently confused the nature of the exposure, indicating that exposed fish were the controls and vice versa. However, these results are not conclusive because of the high degree of effluent dilution at the exposure site. Concentrations of known tainting compounds (such as phenol) are below established tainting thresholds at this site.

A comparison of the results of the twelve panelists completing both the perch and rainbow trout tests shows that the number of correct responses and percentage of correct identifications were significantly higher for the perch test.

Although the Lake St. Francis yellow perch were perceived to have a taint, no chlorophenol or chlorobenzene compounds were detected in the Lake St. Francis yellow perch used for the sensory analysis. The off-odour in the perch as opposed to the trout may, therefore, be due to the longer exposure of the indigenous species to low-levels of contaminants, or to species differences in the

uptake and retention of tainting compounds. Furthermore, variability in the collection techniques used for fish from Lake St. Lawrence versus Lake St. Francis may have had an effect on the observed odour in the downstream fish. Significant differences in concentrations of some PAH compounds found in previous tissue analyses of perch from Lake St. Lawrence and Lake St. Francis leads to the speculation that the off-odour may also be due to chemical contaminants from other sources.

These two studies assisted in the definition of environmental concerns from the public perspective for this RAP area, and in addressing the International Joint Commission proposed delisting criteria for tainting potential. The sensory test and results reported here provide useful tools for evaluating the tainting potential of pulp mill discharges and for assessing perceived consumer quality of the fish exposed to these effluents.

5.0 RECOMMENDATIONS

As a result of the inconclusive results of this study, it is recommended that further studies be conducted on the St. Lawrence River to identify the source and magnitude of the observed off-odours in the fish. Future studies should initially address the question of why off-flavours were found in the indigenous yellow perch, but not in the caged rainbow trout. Accordingly, these studies should be based on whether this phenomenon was due to:

(1) the longer exposure period of indigenous species to low-levels of tainting compounds;
(2) species differences in uptake and retention of tainting compounds;
(3) different sampling techniques for yellow perch upstream and downstream; and/or
(4) exposure of the perch to additional contaminants, such as PAHs, further downstream of the mill.

Additional studies should involve:

(1) laboratory exposure bioassays of fish to Domtar effluent to determine if compounds in this discharge may be contributing to the taint found in the yellow perch;
(2) laboratory exposure bioassays of fish to effluent from potential industrial and/or muncipal effluents to determine if other local sources may be contributing to the taint; and
(3) improved modelling of the zone of exceedance of the potential tainting threshold coupled with fisheries data on fish distribution in this zone.

The laboratory bioassay studies should be based on a series of exposures to various concentrations of effluent, and subsequent sensory evaluation of the exposed fish. A range of concentrations

from 0.1 to 5.0% (v/v) is suggested. Fish should also be exposed to river water from upstream of the source as controls. Ideally the exposures should be conducted using indigenous yellow perch caught upstream of the source. However, because of their greater availability and amenability to bioassay procedures, rainbow trout may be used in addition to or instead of the perch. Again, an extended exposure duration of 96 hours is recommended to ensure that the maximum uptake of tainting compounds is realized, and to allow comparison with the results of this study. Sensory evaluations should be conducted using the same procedures and as many as possible of the same panelists used in this study.

These proposed studies would assist in resolving the incongruities suggested by the results of the study presented in this report.

6.0 LITERATURE CITED

American Society for Testing and Materials. 1968. Manual on sensory testing methods. ASTM STP 434. Philadelphia: American Society for Testing and Materials. 77 p.

Cohen, J.M., L.J. Kampshake, E.K. Harris and R.L. Woodward. 1960. Taste threshold concentration of metals in drinking water. Journal A.W.W.A. 52: 660-670.

Connell, D.W. and G.F. Miller. 1981. Petroleum hydrocarbons in aquatic ecosystems - behavior and effects of sublethal concentrations: Part 2. C.R.C. Critical Reviews in Environ. Control 11(2): 105-162.

Cook, W.H., F.A. Farmer, O.E. Kristiansen, K. Reid, J. Reid and R. Rowbottom. 1973. The effect of pulp and paper mill effluents on the taste and odour of the receiving water and the fish therein. Pulp & Paper Canada 113: T97-T106.

Farmer, F.A., H.R. Neilson, and D. Esar. 1973. Flavor evaluation by triangle and hedonic scale tests of fish exposed to pulp mill effluents. Can. Inst. Food Sci. Technol. J. 6(1): 12-16.

Findlay, D.M. and V.A. Naish. 1979. Nature and sources of tainting in a kraft mill. Prep. by Domtar Research Centre for the Environmental Protection Service, Environment Canada. CPAR Rept. No. 775-2. 59 p.

Findlay, D.M., P. Gregoire, S.R. Megraw, V.A. Naish and R.F. Ross. 1983. An evaluation of the dispersion, dilution and tainting characteristics of the Cornwall effluent plume - 1983. Domtar Research Report, Project No. 82-6210-01.

GESAMP (IMO/FAO/Unesco/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Pollution). 1989. The evaluation of the hazards of harmful substances carried by ships: Revision of GESAMP Reports and Studies No. 17. GESAMP Reports and Studies No. 35. 211 p.

Gordon, M.R., J.C. Meuller and C.C. Walden. 1980. Effect of biotreatment on fish tainting propensity of bleached kraft whole mill effluent. Trans. Tech. Sect. Can. Pulp Paper Assoc. Vol. 6. March, 1980. TR 2-8.

Larmond, E. 1977. Laboratory methods for sensory evaluation of food. Research Branch, Canada Dept. of Agriculture. Publ. 1637. 73 p.

Megraw, S.R. 1979. Environmental impact study of the St. Lawrence River - Cornwall. Domtar Research Report, Project No. 79-3428-01.

Motohiro, T. 1983. Tainted fish caused by petroleum compounds - a review. Wat. Sci. Tech. 15 (6/7): 75-84.

Ontario Ministry of the Environment. 1984. Water management - goals, policies, objectives and implementation procedures of the Ministry of the Environment. 70 pp.

Paasivirta, J. J. Knuutinen, J. Tarhanen, T. Kuokkanen, K. Surma-Aho. R. Paukku, H. Kaariainen, M. Lahtipera, and A. Veijanen. 1983. Potential off-flavour compounds from chloro-bleaching of pulp and chlorodisinfection of water. Wat. Sci. Tech. 15(6/7): 97-104.

Poels, C.L.M., R. Fischer, K Fukawa, P. Howgate, B.G. Maddock, G. Persoone, R.R. Stephenson and W.J. Bontinck. 1988. Establishment of a test guideline for the evaluation of fish tainting. Chemosphere 17: 751-765.

Shumway, D.L. and J. R. Palensky. 1973. Impairment of the flavor of fish by water pollutants. Environmental Protection Agency, Ecological Research Series Rept. EPA-R3-73-010, February 1973. 80 p.

Tidmarsh, W.G. and R.G. Ackman. 1986. Fish tainting and hydrocarbons in the environment: a perspective. Spill Tech. Newsletter II (3): 76-86.